

A DECADE OF DISCOVERY:**Experiments with the Get Away Special (GAS) Canister**

We say we live in a technical age; science is worshipped as a God - a new elemental force more powerful than Zeus, but with higher energy bills. Yet, in this new age most of the worshippers still standback, timid and afraid to approach the holy - of - holies. Sadly, one of these shy supplicants is one that could benefit the most - American Public Education. It seems ironic that the vast system of national education does not utilize one of the greatest means of expanding knowledge - the vast resources and opportunities provided by NASA in the field of space research - in particular, the relatively cheap access to extraterrestrial environment provided by the Shuttle Program. This is especially unfortunate considering the state of public education in this country; and public schools, even private ones, are in trouble are they not? Some are; some are not.

I have the privilege of teaching at Booker T. Washington's High School for Engineering Professions (HSEP) in Houston, Texas, a college preparatory school with an international reputation for educating students in mathematics and sciences. Due to the nature of the school and its location, the school and NASA have a long-standing relationship with many aerospace and educational projects. But, the school's decision to conduct student constructed and supervised microgravity experiments initiated a new level in hands-on experience. Though students with aptitudes in science at a school with its own planetarium, observatory, satellite station, wind tunnel, robotics lab, etc. are not unfamiliar with scientific experiments, the Shuttle experiments were "extraordinary". The contrast between classroom material and the experience of planning, participating in the construction and launch, and opening the canister in their own labs was incomparable. What the students gained from these experiences was one of the high points in public education and far more valuable than other educational programs of equal cost. Like HSEP's previously flown experiments, the experiments on STS-42 were contained in three layers of a GAS canister. The first layer housed the Heterogeneous Flow Experiment, to test the commercial application of space exploration; layer two housed an Artemia Salinas Growth Experiment, a test to determine the success and range of food production in microgravity for longer future missions; and layer three, reserved for the computer and monitoring equipment. What was learned from these experiments; and, more importantly, what impact they had on education on a broader scale is the subject of this paper.

LAYER ONE: The Heterogeneous Flow Experiment

The migration of an air bubble in a fluid environment (The Heterogeneous Flow Experiment) has long been a subject of expe-

rimentation; however, this phenomenon must be studied in zero gravity, that is, without the external influence of buoyancy. The findings of such experiments can be applied to the making of high technology glass, free from any imperfections; the advantages in the fields of cybernetics, high resolution optics, etc., can only be imagined. Such glass is impossible to make on earth because of air trapped in pockets in the molten glass. Theoretically, there are a number of ways in which these bubbles can be removed in a weightless environment; one of which is the application of a thermal gradient through a fluid.

A thermal gradient, is formed when the temperature of the fluid varies uniformly along its length. When an air bubble is introduced into a fluid environment containing a thermal gradient, it is acted upon by a force which moves it toward the warmer end of the fluid. This is a result of the variation in interfacial tension (surface tension at the interface between non-mixing fluids) at different temperatures. When there is a wide variation of interfacial tension, as in a thermal gradient fluids both inside the bubble (air) and around the bubble (water) are set in motion. This motion tends to carry the bubble in the direction of decreasing interfacial tension, the warmer end.

Because of a temperature gradient, the fluid on the right side of the bubble is hotter than that on the left, giving the fluid molecules on the heated right side a comparatively greater molecular motion. The rapid motion of the molecules causes inelastic collisions on the right side, forcing the bubble to move to the left. However, The fluid on the left, cooler side, is denser than the fluid on the right. As the bubble tries to move to the left, there is a tendency for the denser fluid to push back directing the bubble back to the less dense, right side, creating a counter force.

To further complicate the matter, a large bubble has a large surface area, thus increasing the number of molecular collisions and making kinetic energy the dominant force. Thus, a large bubble tends to move away from the heat source. A small bubble, however, receives less molecular hits and kinetic energy becomes a less significant force; the smaller bubble tends to move towards the heat source. The exact size needed to move one direction or another has been theorized, but there is some controversy as to the accuracy of the theories and other variables, bubble expansion, external fluid density, degree of temperature variations, etc.

Scientists have, in the past, theorized the movement of bubbles under the influence of thermal gradients. Through the years, a formula was formed through extensive experimentation. Derived from a combination of other formulas, the formula gives the migration velocity of a bubble. The formula consists of the product of two equations of velocity. The dimensionless velocity U and the natural scale velocity

V, where

$$U = 1/2 - 301/14400 N \quad (1)$$

ma

and

$$V = (T' \cdot l \cdot o' \cdot l \cdot a) / n \quad (2)$$

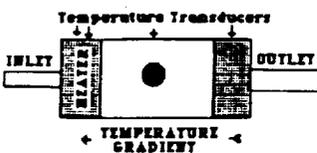
The notation in equation (2) is as follows: T' is the thermal gradient of the liquid far away from the bubble, o' is the rate of change of the interfacial tension with temperature, a is the bubble radius, and n is the absolute viscosity of the liquid. The term N is defined by

$$N = a / V$$

where N is the thermal diffusivity of the liquid.

This theory was proposed and largely proven in laboratories on earth, but experimentation in weightlessness is sadly lacking. It was of considerable importance to test theories and gather empirical data in zero gravity where no other forces than the thermal gradient could affect results.

TRAY 1: HETEROGENEOUS FLOW EXPERIMENT

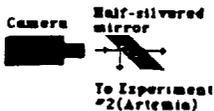


The Air/Water Chamber contains triple distilled water. The ends are made of aluminum. In flight, the computer injects measured amounts of air into the chamber. These air bubbles should be different sizes.

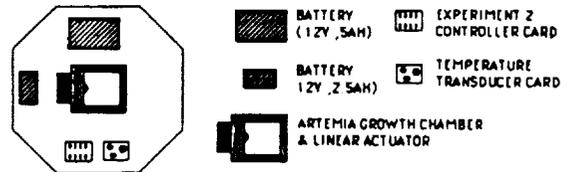
The inlet end contains a heater. Its temperature is monitored by a temperature/transducer located at the inlet end. The computer then controls the temperature gradient. Three other temperatures are recorded to allow for temperature gradient calculations.

Research indicates that the direction and speed of the bubble movement should depend on both bubble size and temperature gradient. These effects are "masked" by gravity. In microgravity, these effects will be able to be studied.

The motion of the bubble will be photographed by the 8 mm camera in a single frame mode. The half-silvered mirror will allow photographs of both experiments. The computer will energize the proper lamp to photograph the correct experiment.



TRAY 2: ARTEMIA GROWTH EXPERIMENT



The Artemia (Brine Shrimp) Experiment will attempt to hatch and grow brine shrimp in microgravity. The chamber contains distilled water and air.



The linear actuator will inject the eggs, salt, food and time-released oxygen tablets in the beginning of the flight.



The eggs will hatch in 24 to 48 hours. Adequate food and oxygen will hopefully keep the shrimp alive for the flight and return.



The shrimp's hatching and growth will be recorded by the camera in tray 1 through the half-silvered mirror.

EXPERIMENTAL PROCEDURES

The Heterogeneous Flow Experiment, housed in tray one of the G.A.S. cannister, contained the following equipment: the air/water chamber filled with triple distilled water, a heater, a pump, a battery, an eight millimeter camera, a half-silvered mirror, a reflector lamp and an experiment controller card. Once orbit was achieved, the water was heated to 20°C. After the water reached the correct temperature, the computer turned on the pump which pushed an exact amount of air through the inlet. Immediately thereafter, the bubbles passed through a mesh grill and into the water chamber, a transparent cylinder with circular aluminum end blocks containing the inlet and outlet tubes. The inlet end block contained the heater and the outlet block contained a temperature transducer to remove heat. The displaced water was purged through the outlet. The water was again heated; this time to 40°C. Another set of bubbles were pushed into the water chamber. Finally, the water was heated to 60°C and the process was repeated.

The temperature in the chamber was monitored by the computer in four identical sets of EPROM's (Eraseable Read Only Memory Chips) for increased reliability. The computer also turned on the lamp and camera at five minute intervals to create a photographic record of the activity in the bubble chamber.

RESULTS

The results of this experiment were most interesting. As expected, free from the extraneous influence of gravity, the bubbles moved only along the axis of the thermal gradient, showing that this was the only force to be considered. As predicted, the bubbles entered the inlet (heated) end at the highest velocity, but the speed gradually decreased as the bubbles travelled through the cooler fluid. Gradually, some bubbles stopped in a "no man's land", the greatest fluid density at the cool end of the cylinder preventing them from actually reaching the outlet end. They remained there in an unquiet equilibrium. Some bubbles actually, after coming to a slow stop, slowly began reversing direction and moved back to the heat source. Since it was impossible to guarantee that all bubbles were of the same size, this behavior was expected.

CONCLUSIONS

This strongly indicates that theories predicting bubble movement in microgravity can be used to create optically perfect glass. It is also clear that more experimentation will be required before optically perfect glass can be manufactured in space with a high degree of reliability.

RECOMMENDATIONS

The action of the bubbles supported theoretical predictions, but some of the unanticipated behavior suggests further modification and refinement of basic theory. Interestingly enough, an observed phenomenon lent credence to a theory that a moving bubble in zero gravity is not round. Rather, it is bullet shaped with the point facing the direction of movement. Experimental data tended to support this belief. Though the experiment was largely successful, certain improvements and modifications should be considered for future experimentation.

1. More tests and refinements of macro photography, particularly when shooting through the varying viscosity/refraction index mediums, is in order.
2. Pictures should be taken more frequently than five minute intervals.
3. Experiments should be conducted with different chamber fluids.
4. In conjunction with increased photographic clarity and more frequent observations, further investigation of bubble shapes in zero gravity, particularly the bullet shape, should be conducted.

LAYER TWO: The Artemia Growth Experiment

One of the major obstacles facing further expansion in space is quite simply, food. The cost in weight and space of bulk, non-replenishable food effectively limits the length of manned space missions. This makes the space station and proposed lunar base painfully dependent on regular supply missions and interplanetary travel almost impossible. Growing food in space, however, may not be a simple proposition. Zero gravity can adversely affect, even destroy, organic systems; and an insufficient number of experiments concerning the germination and development of egg cells have been attempted in weightlessness. HSEP's experiment in tray number two was one of the experiments of this type.

EXPERIMENTAL PROCEDURES

The experiment tested the ability of Artemia Salina (brine shrimp) to hatch in zero gravity. Artemia Salina, a relative of the lobster, was picked for the experiment due to the hardy nature of the organism. It has the ability to survive in inordinately saline environments; the eggs may either hatch immediately after mating or lie dormant for extended periods. Dormant eggs develop hard, brown shells and can be dried and kept for years before being hatched in salt water. The eggs can survive temperature extremes from -190°C to $+150^{\circ}\text{C}$ and still hatch and grow normally. Not only could this organism

provide nourishment via the "plankton soup" survival diet, but also by providing a vital link in the food chain of a long-term habitation module. It would also strongly indicate that similar life forms (lobster, etc.) could be grown in microgravity.

The experiment contained several distinct components: a growth chamber, an actuator assembly, experiment controller and temperature transducer cards, two batteries and a silvered half mirror which allowed a camera in tray one to periodically take pictures of the activity in the growth chamber.

The 4" X 4" X 3" growth chamber was made of one fourth inch plexiglass and contained a salt water solution. The actuator assembly had an Airpax actuator and a modified syringe, which contained shrimp eggs and a food supply (rice hulls). The experiment was activated eight minutes into orbit: a heater was turned on that maintained the culture medium at a constant +23°C for the remainder of the shuttle flight. When the culture medium reached the prescribed temperature, the actuator injected eggs, food and time released oxygen tablets into the saline solution. The temperature in the growth chamber was recorded by the computer in four identical sets of EPROM's for increased reliability. The eggs hatched in twenty-four to forty-eight hours and the food and oxygen tablets provided a life-sustaining environment. The camera was used to monitor the injection of the eggs, their hatching and growth. (A light was turned on at appropriate times to allow for picture taking, with a picture taken every five minutes.) The pictures were used to compare artemia growth with a control experiment conducted simultaneously at B.T. Washington/HSEP laboratories.

RESULTS

After landing, the growth chamber solution was subjected to various examinations: a microscopic examination, comparison against the control, analysis of photographs and examination by electron microscope.

Initial microscopic examination was performed as soon as the growth chamber was delivered to Washington/HSEP laboratories. Pipettes of fluid were withdrawn from various locations in the growth chamber and examined under the microscope. In essence, a quadrant, random sampling method of counting, similar to wildlife surveys, was used. By counting the fragments of hatched shrimp and unhatched egg, while discounting food debris, it was ascertained the approximately 60 per cent of the shrimp eggs hatched. When comparing these results with the control experiment, which was terminated at the time the orbital experiment ceased, similar figures were recorded. Certain questions arose at this point; however, did an unexpected temperature rise in the growth solution kill the hatchlings? (An unanticipated, temporary temperature rise to 40°C occurred later in the mission.)

Did the long delay from the end of the experiment until the opening of the canister kill them from lack of food and oxygen; or were the shrimp, born and developed in zero gravity, literally torn apart by entry into Earth's gravitational field? Experiments are currently being designed at Washington's science labs to investigate these questions. At the time of this report, electron microscope photographs had not yet been completed by an outside laboratory, but are expected.

CONCLUSIONS

Though not all tests have been concluded, it is apparent that *Artemia Salinas* can be hatched in microgravity. This also strongly indicates that similar life forms: crustaceans, lobster, etc., could also be grown in space, thus providing a desirable food source for extended space missions. It also suggests further studies, particularly in the area of life forms born in weightlessness and their adaptability to gravitational fields.

RECOMMENDATIONS

1. A second actuator should be added to the growth chamber to inject a fixative solution at the termination of the experiment. This would preserve the organic samples in their original condition at the end of the experiment.
2. A heat sink should be added to tray one (Heterogeneous Flow Experiment) so the excess heat can be extracted from the canister interior. This was suggested because the temperature increase in the growth chamber appeared to result from heat generated in the tray one's bubble chamber. Though these two trays, were insulated from each other, there was evidence of a heat leak as tray two showed a steady 1°C/hour temperature rise correlating to the operation of the heater in tray one. At this point the cause of the heat leak can only be inferred, but thermal radiation through the mirror opening or conduction through the bolts holding the trays together are likely explanations. (See Figure 3.)
3. To prevent the liquid in the experiments from freezing in space, the canister was heavily insulated. It was speculated that, perhaps it was "too well" insulated trapping too much heat inside. Any reduction of insulation must be attempted only with considerable trial and error. Most likely, recommendation number two would be a more reasonable, cost-effective approach, with number three viewed as a last solution.
4. More experimentation and refinement of macro lense photography, is in order.

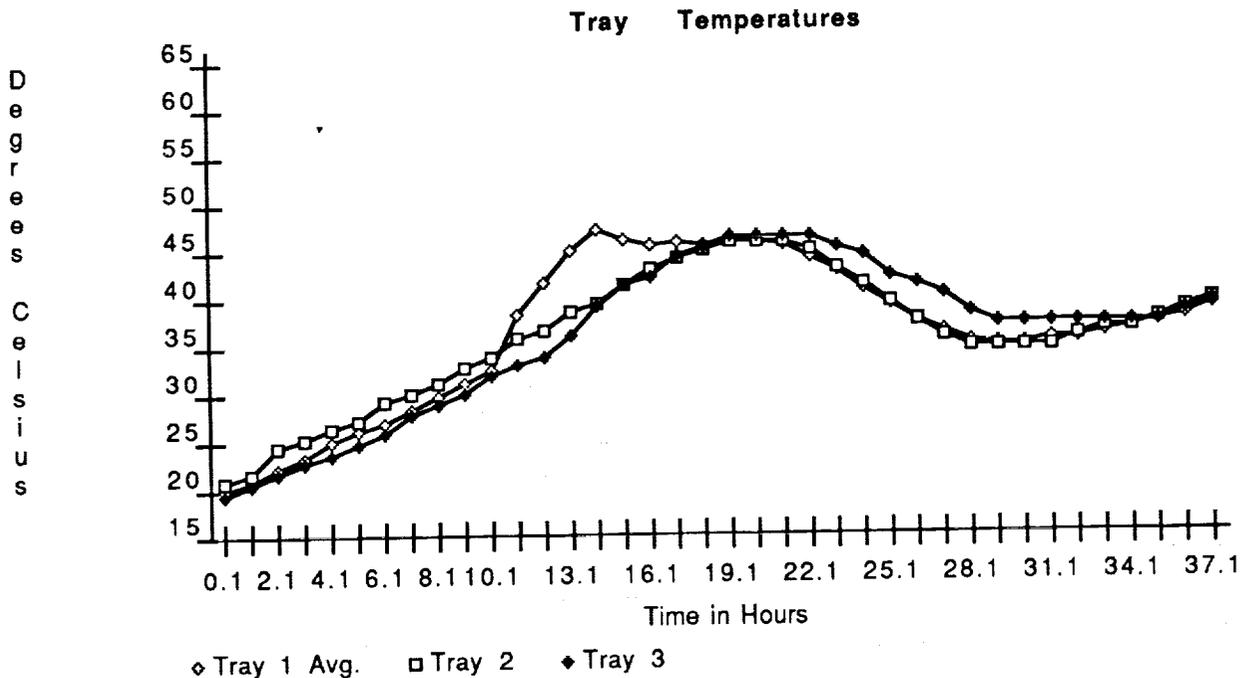


Figure 3.

These experiments, it must be admitted, are not the most important or complex ever to fly on a shuttle. To be candid, they are probably the least so. But, the main purpose of HSEP is education, and the success of the experiments can be determined by the impact on students. In this regard, the shuttle experiments were trend-setting. The actual scientific knowledge gained by the students was significant. These were not textbook experiments, not experiments suggested and set up by an instructor. Instead, these were experiments set up to serve a useful function, where real world value and potential were involved. Every student involved with the project, directly and indirectly, felt they had learned more about science and scientific method from this one project than they had in all of their traditional classes combined. They also learned how to plan larger projects. Not only were the students allowed to help plan the experiments but they also helped build the experimental hardware, plan the control experiment and plan and build the monitoring equipment. The project's student leaders and their helpers learned the importance and key steps of planning larger projects, the value of relegating duties and the significance of team effort. They also learned the value of research before, during and after the project - something very few high school students want to realize. They learned to write better technical reports, once they actually saw their value. Most importantly, as one of my students said, "There aren't really answers, just new questions."

Though an increase of formal, quantitative knowledge is wonderful, the shuttle project served a more noble purpose and the

value of the shuttle experiments was the electrifying effect it had on the student body in general and their desire to learn.

Students need to feel success, to be praised for their accomplishments and to recognize value in their achievements, particular minority students, as most of ours are. The shuttle program gave our students a "shot" of self-esteem like no other educational program has. They felt good about themselves and more eager to attempt difficult and challenging tasks. They were also able to see the value of commitment to a long-term goal, and this has even carried over to classroom and textbook dedication. In fact, once they could see the material in their texts being put to practical application by other students, even the poorest student began working harder. Perhaps too, this attitude was partly the product of student realization that the administration and faculty had enough faith in them to provide this opportunity, even at the sacrifice of budgets in other areas. Pride in the school, which was never low, mushroomed. Even students in Washington's regular program who were not part of the engineering school went about the city proudly proclaiming "I go to Washington". We even saw an increase in foreign students entering our program.

Am I implying that the GAS canister experiments made an urban school a utopia? No. We had a good school before, but because faculty and students care about one another, incurring the expense of the shuttle flight and the cost of building the hardware was just another way of fulfilling our mission - education. And, the shuttle experiments were a good investment. For less than the cost of many programs of questionable worth, we gave our students something valuable for the rest of their lives. What did we get in return other than "a wonderful sense of fulfillment" and pats on the back? I can answer that in real, quantitative terms. If you would visit our school you would not see the scenes portrayed on television. Rather, you would see teachers and students smiling, telling jokes to one another, sharing a doughnut and treating each other with respect. You would see teachers giving their lunch times and sometimes Saturdays to help students, and students volunteering to come in early and stay until seven or eight o'clock to help the teachers. We have never had knives, guns or drugs in HSEP. In fact, a student has never even been sent to visit a principal in over two years. Most of our students come back one, two, ten years later to tell of their success in college and industry - and to thank us for helping them. Are some public schools bad? Yes. Are they all? No. Our teachers and students have found ways to commit their efforts to each other and create genuine learning experiences. The shuttle experiments were just some of the best.

Robert Brienzo

